New Technology Initiatives in Rural Roads and Use of Marginal Materials

Use of Geosynthetics in Low Volume Roads

National Rural Infrastructure Development Agency

Ministry of Rural Development

National Institute of Technology

Warangal, Hyderabad

Lecture 8

Use of Geosynthetics in Low Volume Roads

Presentation Outline

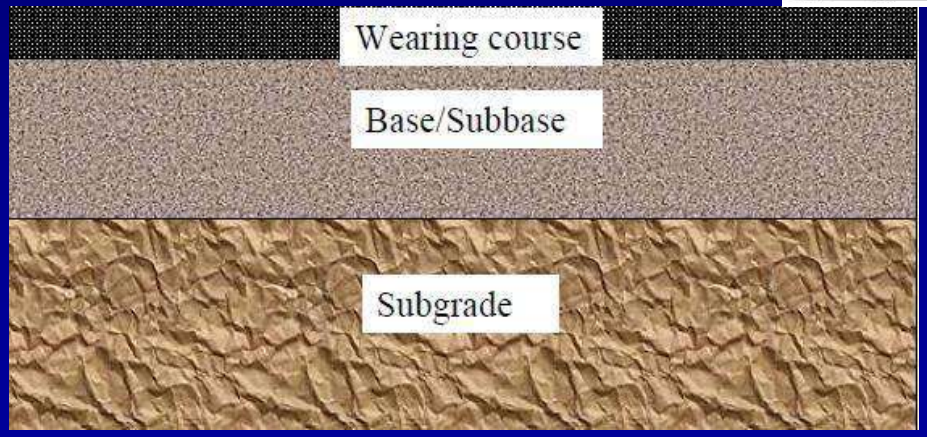
- History of Geosynthetic and Preamble
- Different Type of Geosynthetics
- Main Functions of Geosynthetics
- Major Applications of Geosynthetics
- Major Benefits of Geosynthetics
- IRC Guideline on Geosynthetics
- Discussions!!

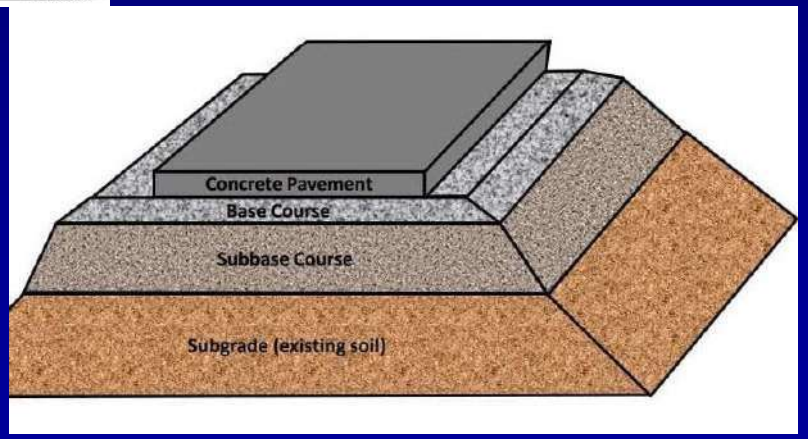
History of Geosynthetics

- First use, South Carolina Highway Department in 1926
- First geotextile in a dam, in 1970-Nonwoven geotextile
- Geofoam applied as a lightweight fill-Norway -1972
- First conference on geosynthetics was held in Paris in 1977
- Reduces the construction time, save consumption of energy
- IRC:SP:59-2019, addressed the following applications
  - Stabilization and reinforcing of pavement layers
  - Separation and filtration and Subsurface and surface drainage
- Under-utilized on LVRs, it takes good people to do good work!

Preamble- Purpose of Pavement

- To support eh traffic laods and provide riding comfort
- Rutting and fatigue cracking failure on roads





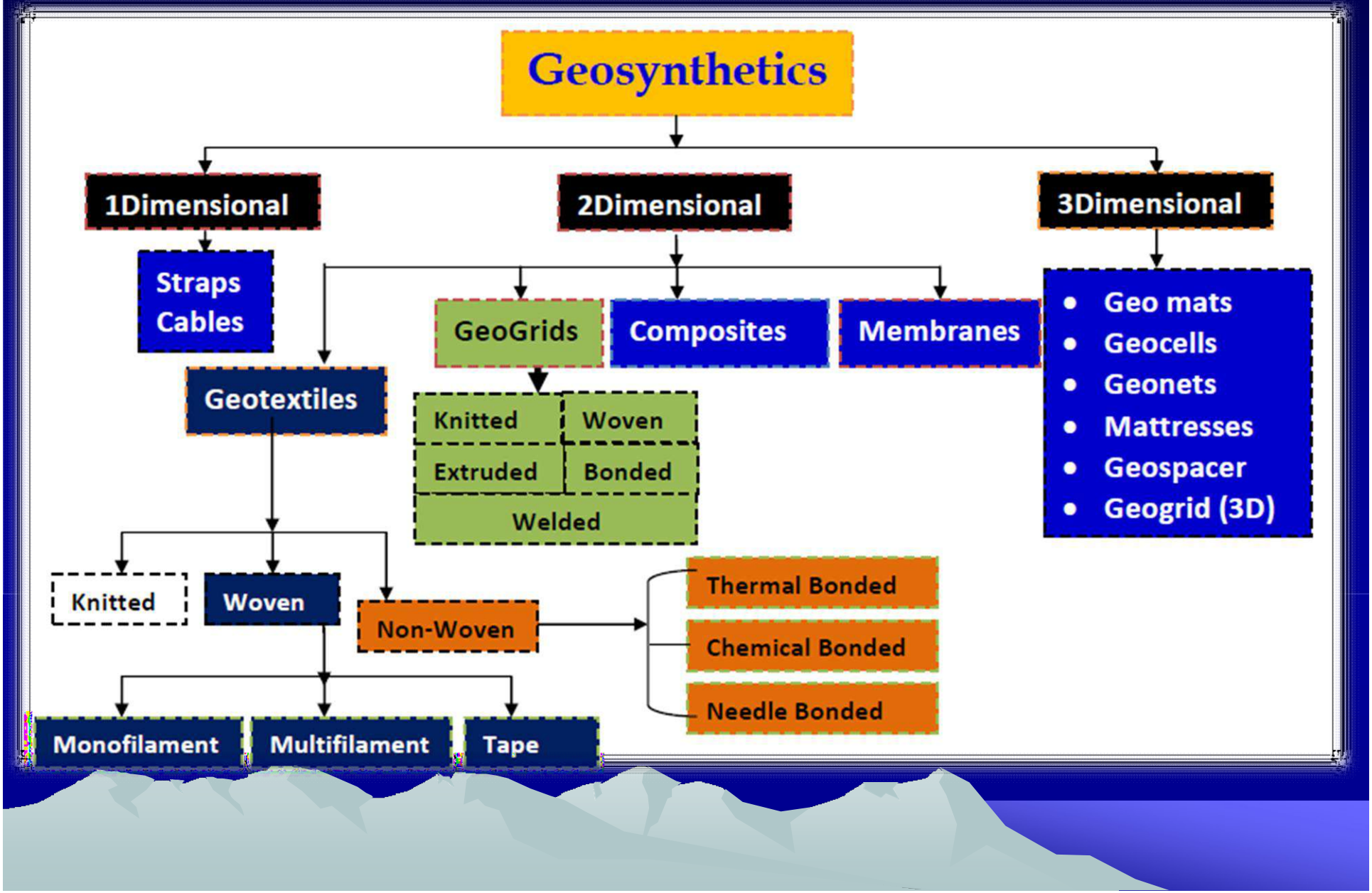
What is a Geosynthetic Material!

- Planar product manufactured from polymeric material used with soil, rock, earth or any other geotechnical engineering related materials as an integral part of a man made project, structure or system.

ASTM D4439

- GS is a generic term for all synthetic material used in pavements/ Geotechnical applications.

Classification Geosynthetics



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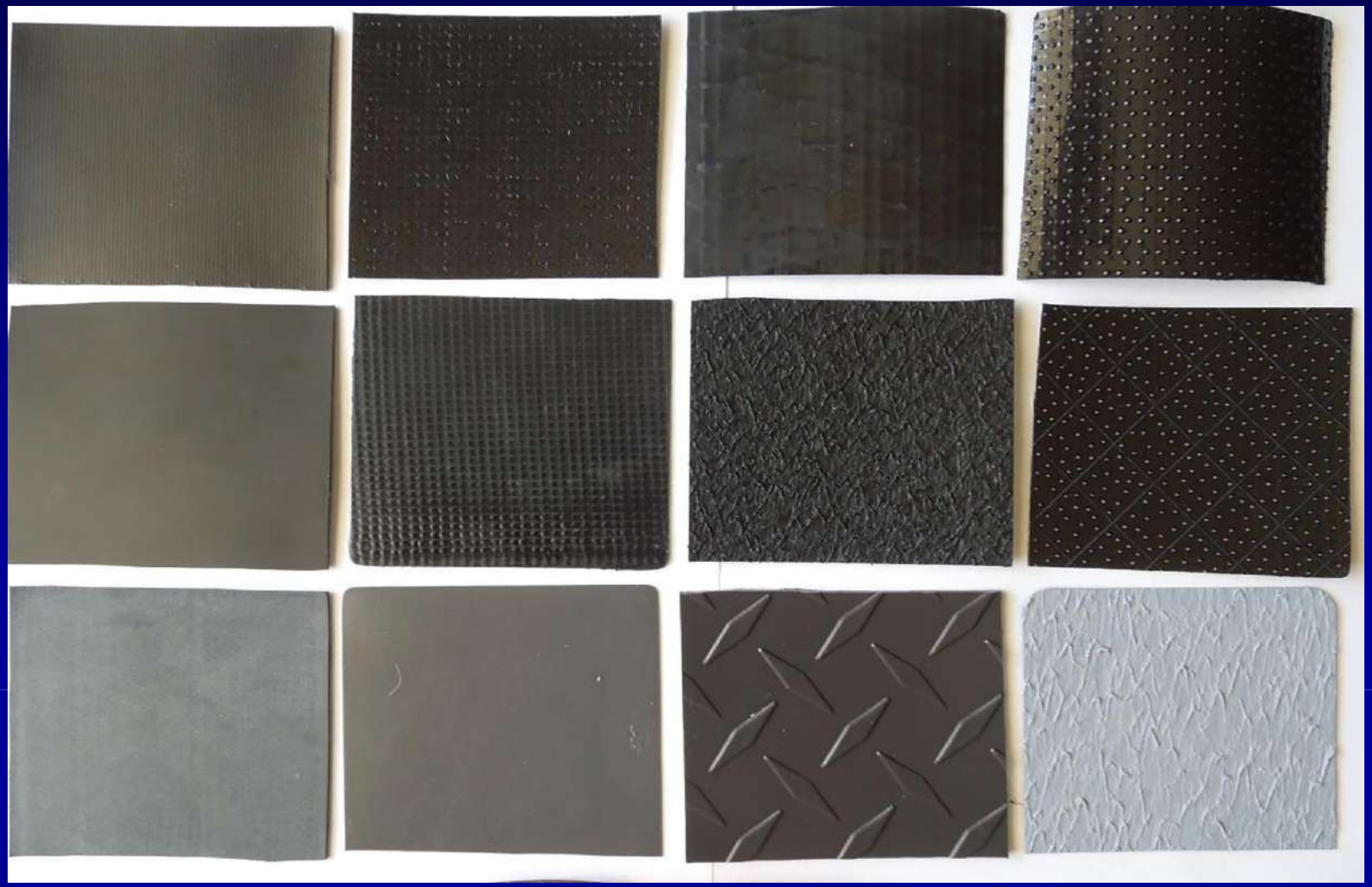
Knitted geotextile

Geomemebra



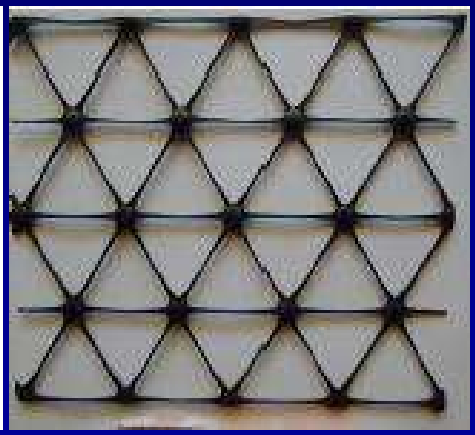
Geogrids

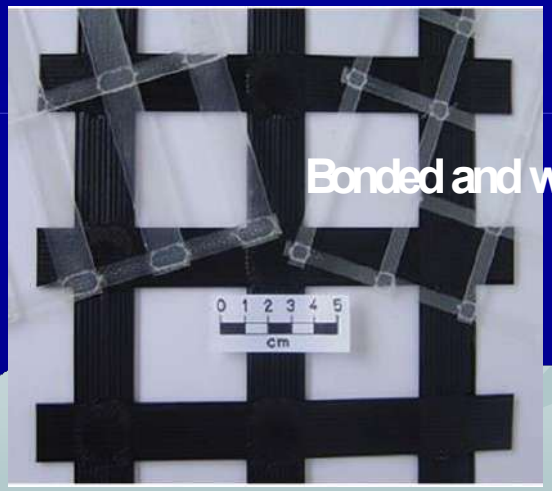
- Formed by a regular network of tensile elements and apertures typically used for reinforcement purposes

(a) **Extruded Geogrids** (i) uniaxial, (ii) biaxial and triaxial;

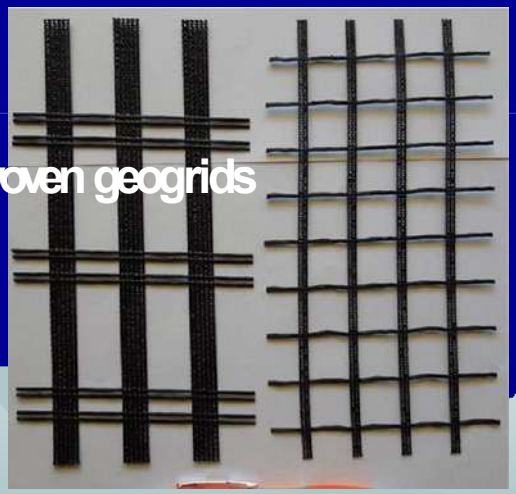
(a)-(i)

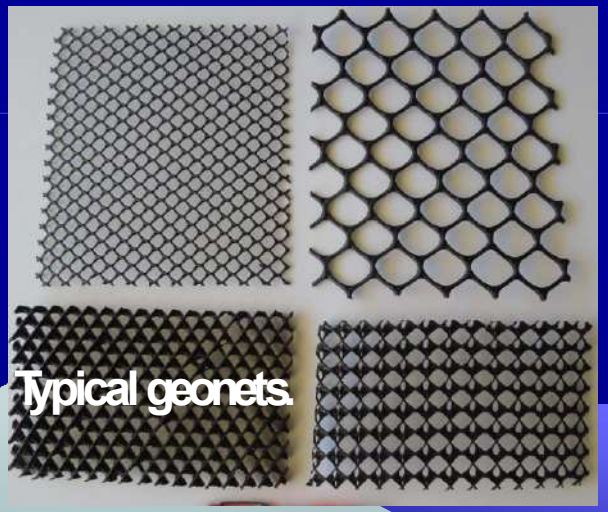
(a)-(ii)





Bonded and woven geogrids

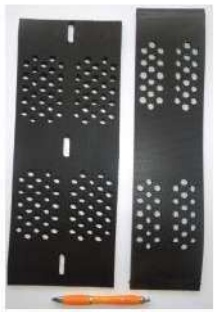




Typical geonets.

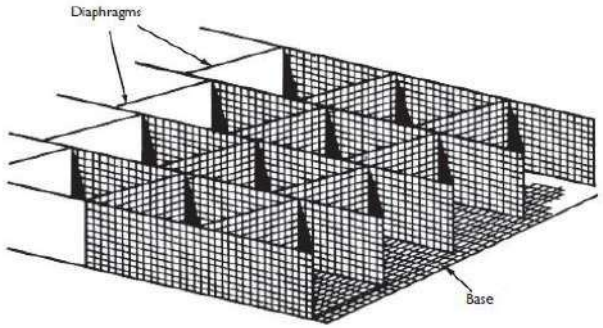
Geocells

- Less work has been done on mechanisms of 3D geocells
- Geocells are apparently much more expensive than geogrids
- Major area of implementation of geocells is in soil stabilization
- Geocells have seen very successful application in subgrade and sub-base stabilization in temporary roads, such as haul roads, in areas with very low-bearing capacity soils such as swampy and sandy areas, and also in railroad ballast stabilization.



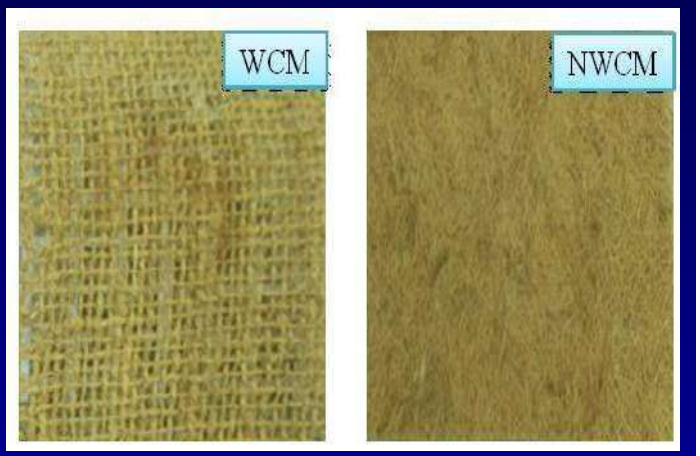
(a)-(i)

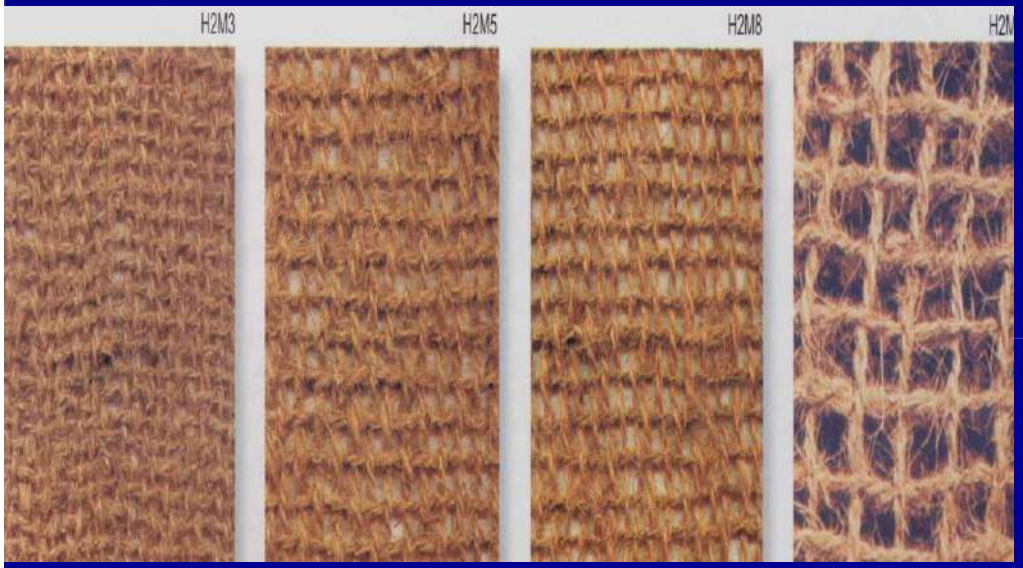
(a)-(ii)



(b)

Coir Based Products





India annual production of 12,597 million tons. Production of coir fiber is 3,69,400 million tons and Utilization of husk is 36% only.


(a)-(i)

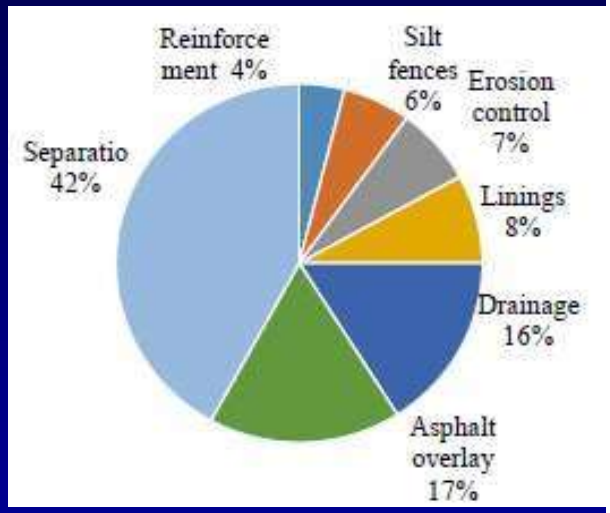

(a)-(ii)

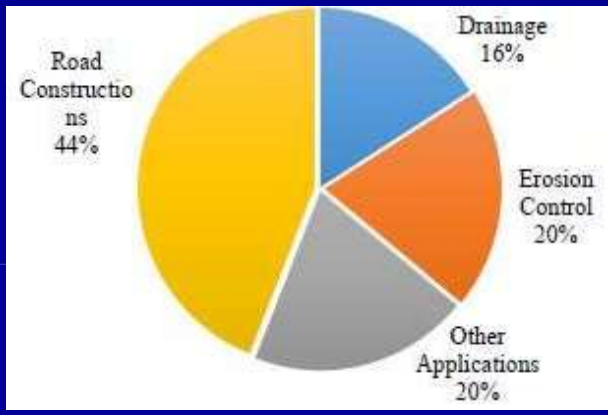
Ranking of Geotextile Based on Performance

#	Types of Geotextile	Rank	Functions		Combination
			Reinforcement	Separation	
1	Geogrid with Non-Woven 1 Coir mat	1	Appropriate in reinforcement,	in Appropriate as separation	Good with gravel sub-base layer II and III
2	Coir Composite	2	Appropriate reinforcement	Appropriate Separation	Suitable with morrum and gravel sub-base layer II and III
3	Woven coir mat	3	in Appropriate Reinforcement	In Appropriate Separation	Suitable for separation/partial reinforcement sub-base layer III
4	Non Woven Coir mat	4	in Appropriate Reinforcement	Appropriate Separation,	Suitable for separation in all the combination

Main Functions of Geosynthetics

- Separation
- Reinforcement
- Drainage
- Filtration
- Erosion Control
- Containment/ Moisture Barriers/Protection





Geosynthetics in Road Construction

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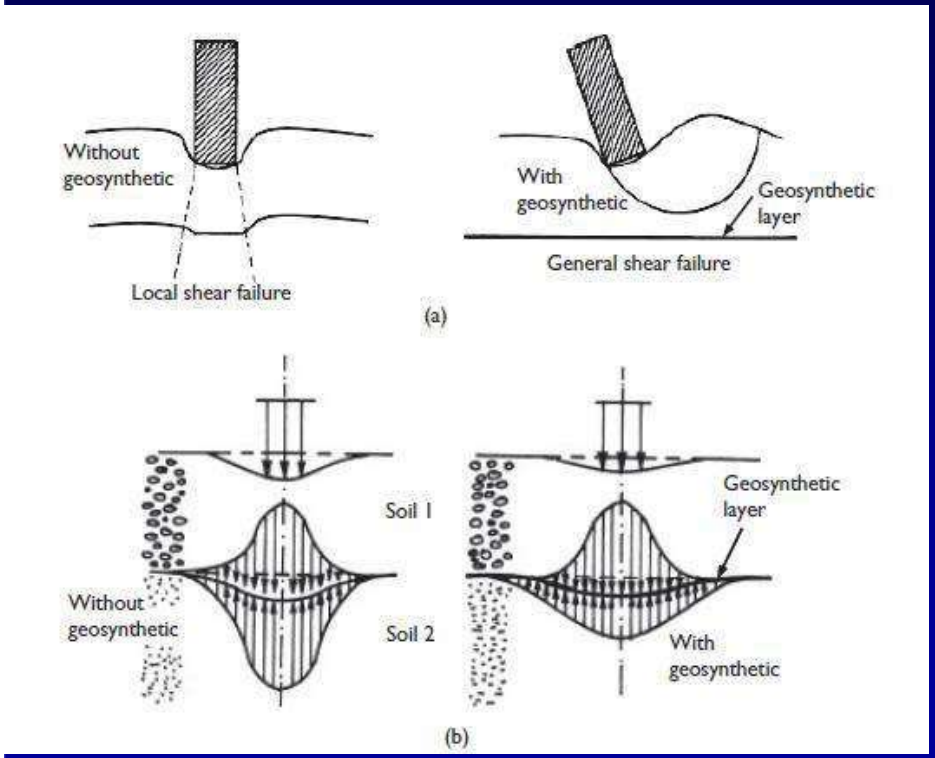
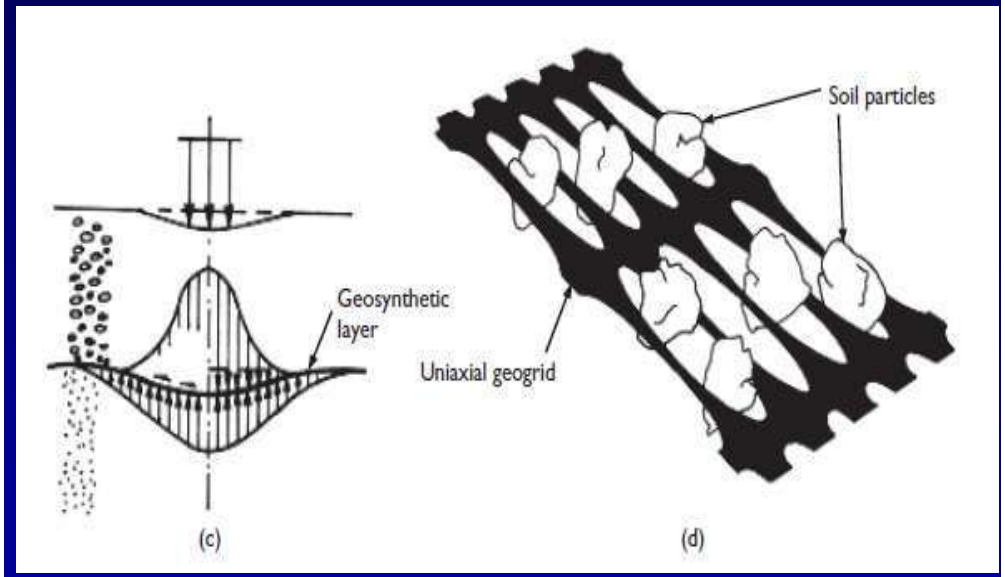
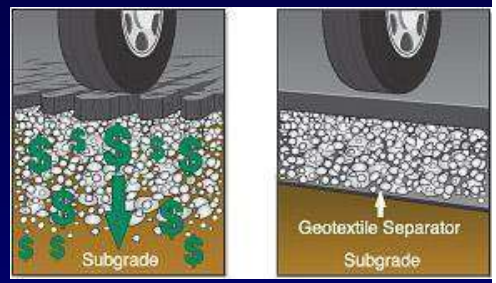




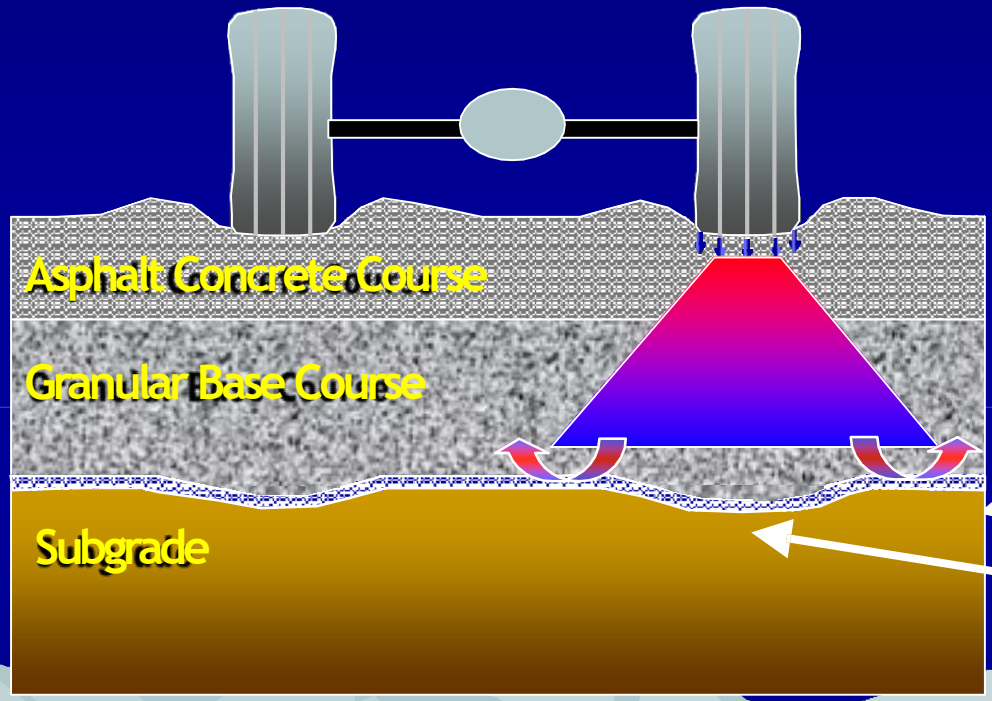
Roles of the geosynthetic reinforcement: (a) causing change of failure mode (b) redistribution of the applied surface load (confinement effect); (c)providing vertical support (membrane effect) (Bourdeau *et al*. (1982) and Espinoza(1994)); (d) providing passive resistance through interlocking of the soil particles (interlocking effect).

Separation



Salient Points:

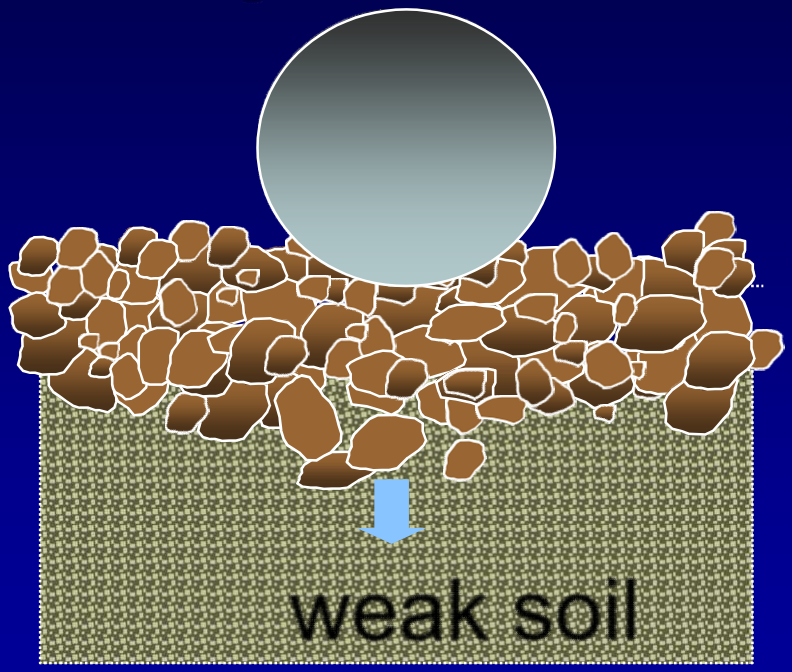
- Geotextile's primary function
- Geotextile modulus is not significant for separation
- Need separation when subgrade CBR < 4%
- Geogrids provide minor separation benefit
- Separation saved 25% on aggregate surfaced road

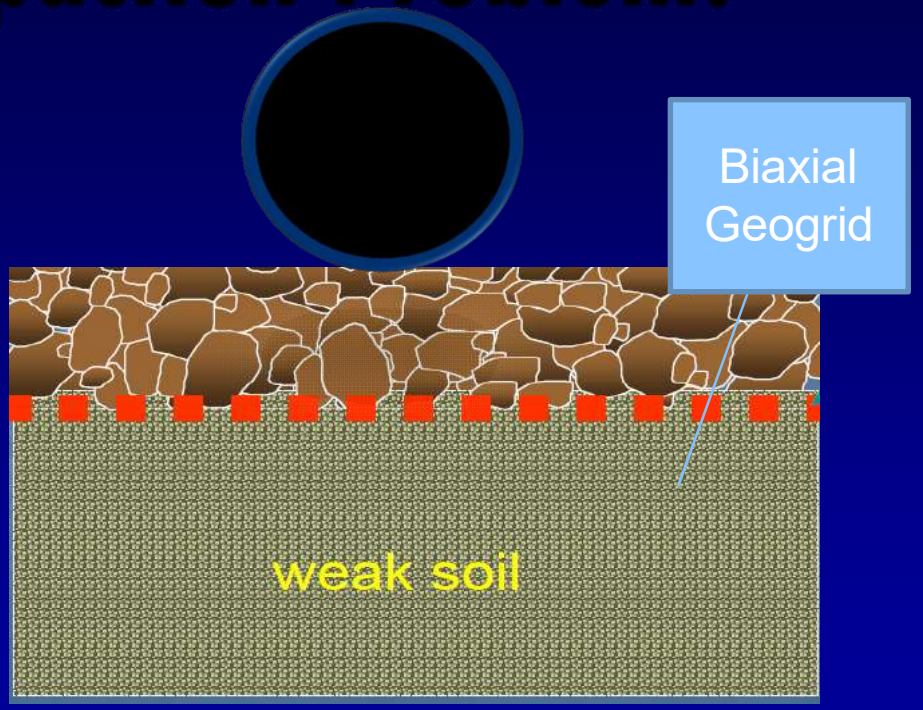


geosynthetic separator

aggregate-subgrade effectively separated

Separation: Compaction Problem!





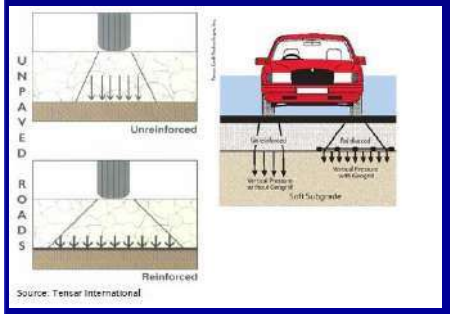
weak soil **Proper Compaction | Possible!**

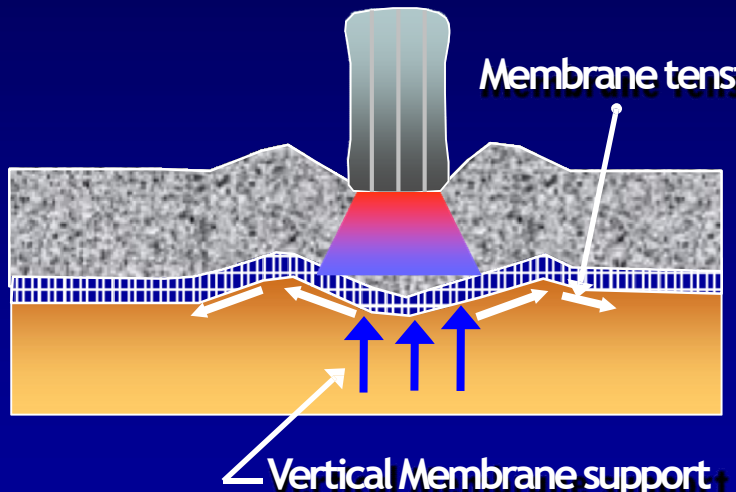
It Prevent fine grained soil from lowering the strength of the load bearing aggregate base course layer.

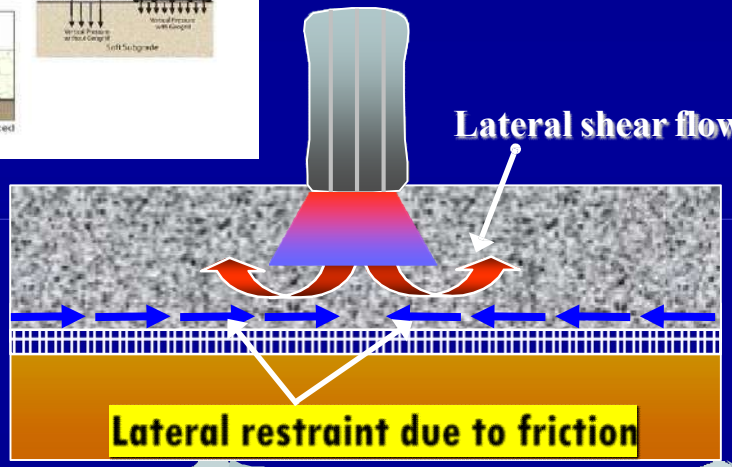
Reinforcement

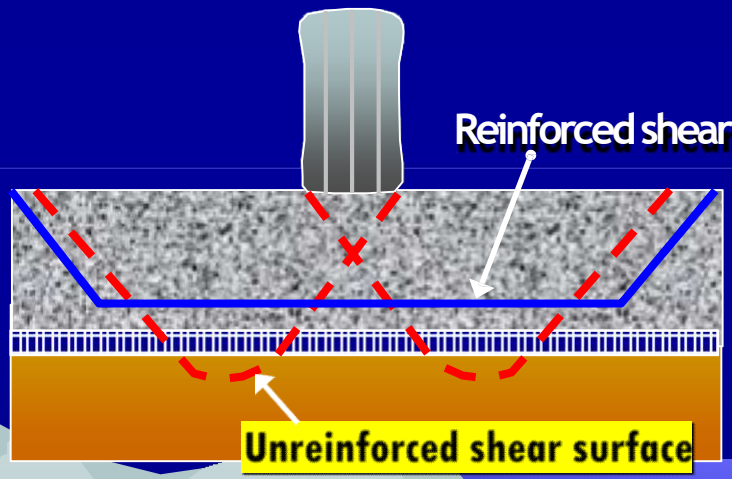
Synergistic improvement of a total system's strength created by introducing a geosynthetic (good in tension) into a soil (good in compression).

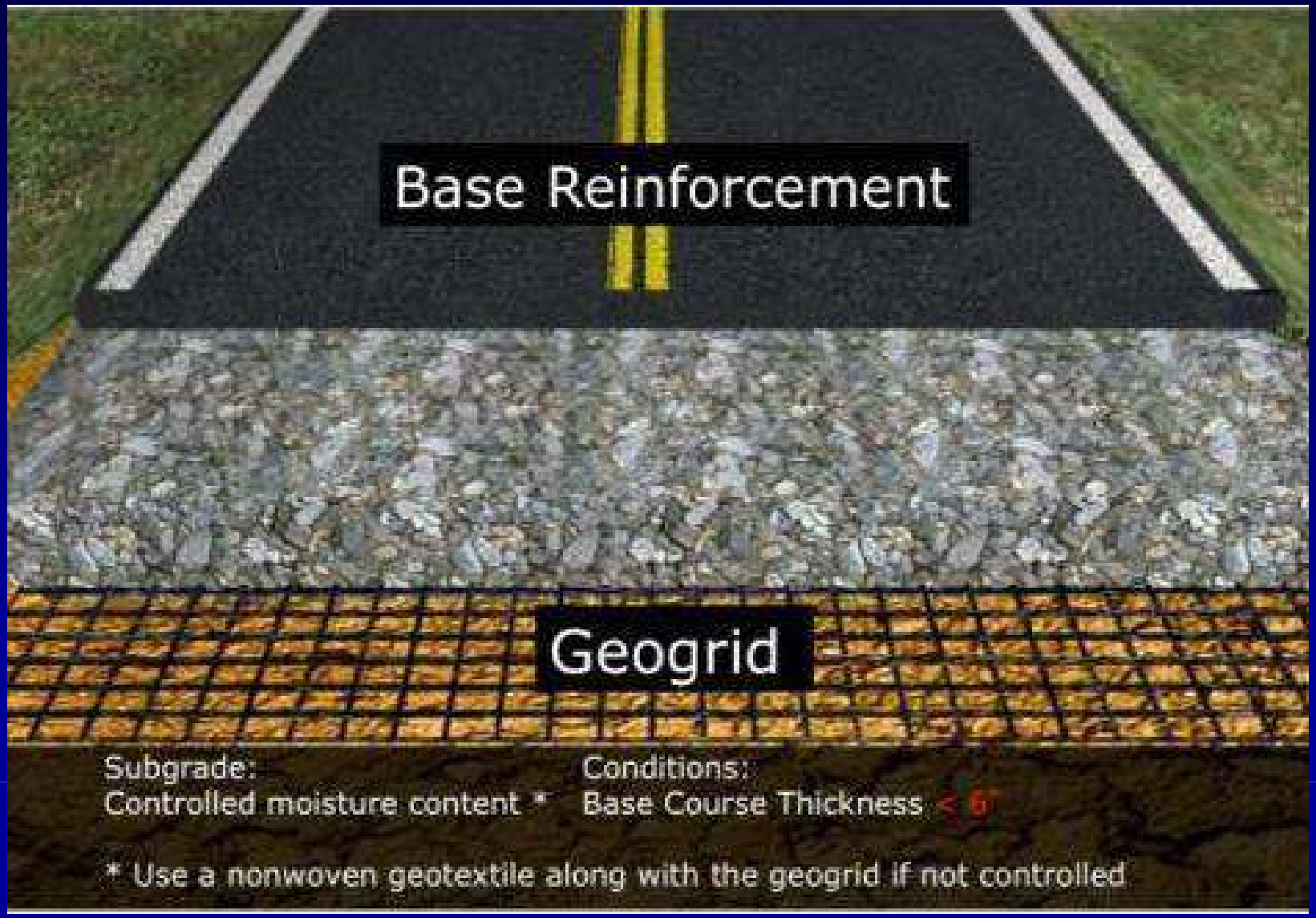
- Reinforcement Mechanisms
- Tensioned membrane effect
- Lateral restraint
- Increased bearing capacity









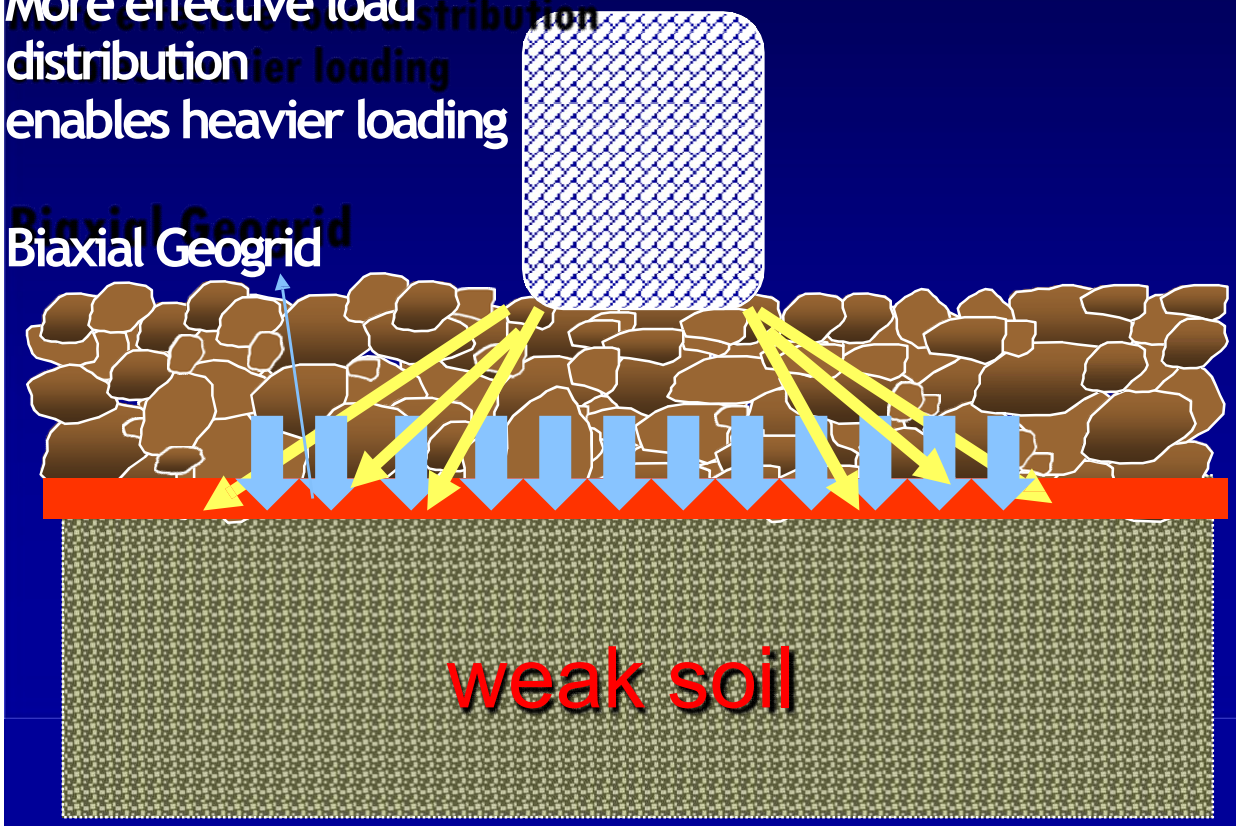

Base Reinforcement
Geogrid
Subgrade:
Controlled moisture content *
Conditions:
Base Course Thickness < 6"
* Use a nonwoven geotextile along with the geogrid if not controlled

Reinforcement

Civil Engineering/Pavement Engineering/ Automobile Engineering Issue!!

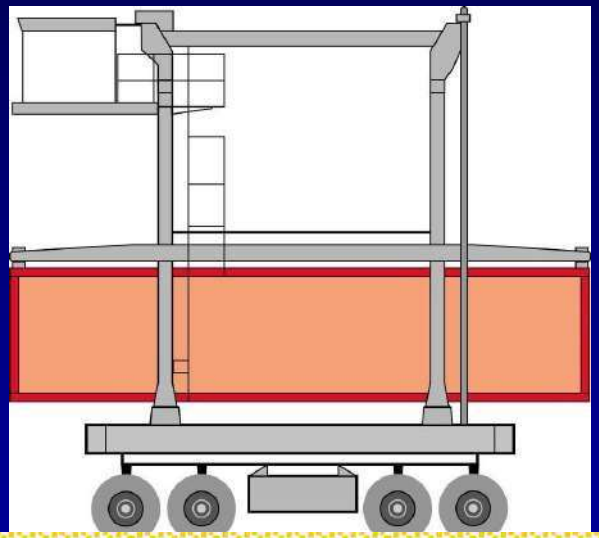
Solution Could be….

More effective load distribution enables heavier loading

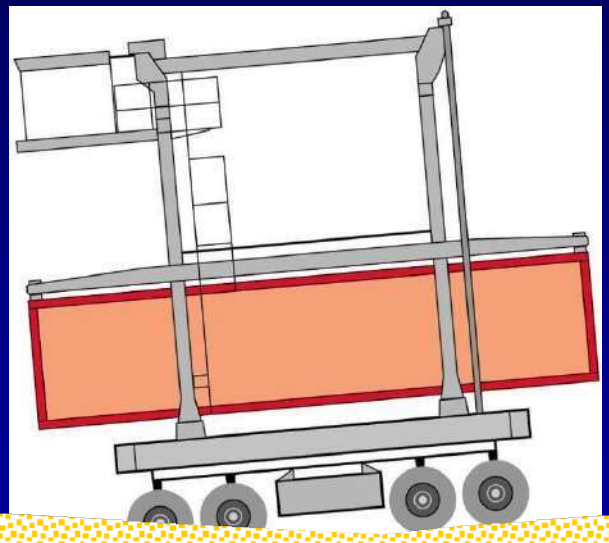


Provides high strength at low strain resulting in reduced aggregate thickness and low vertical deformations.

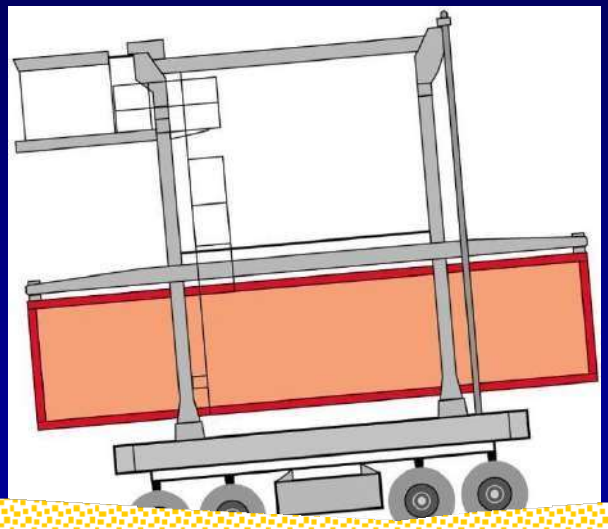
Construction without Geogrid Reinforcement



Weak soil

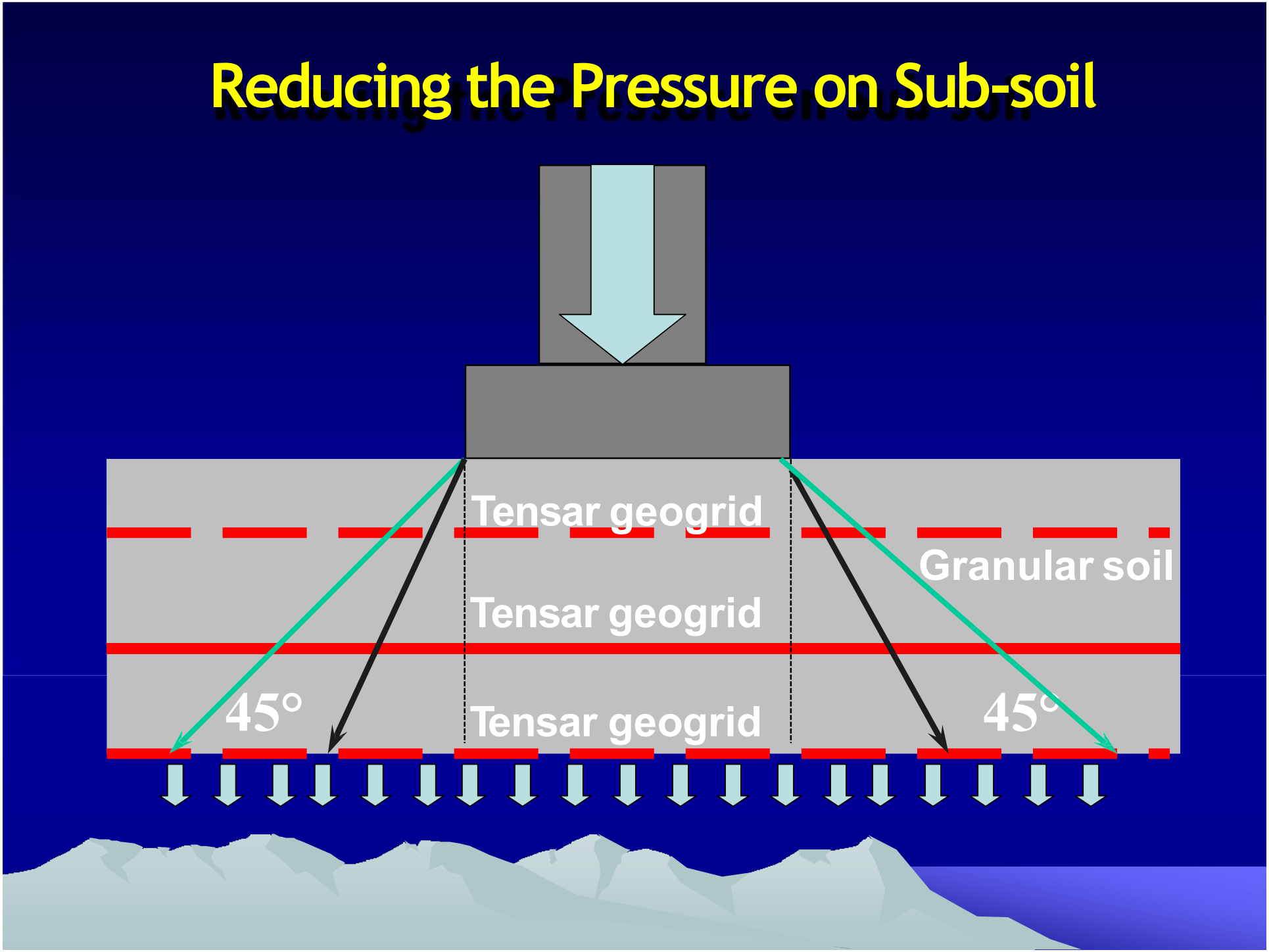


Weak soil

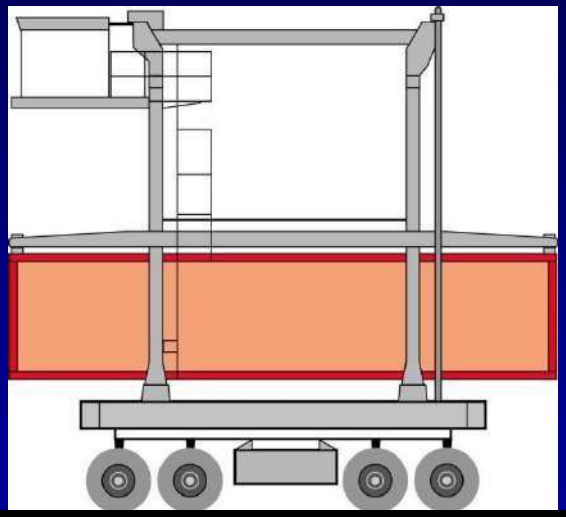


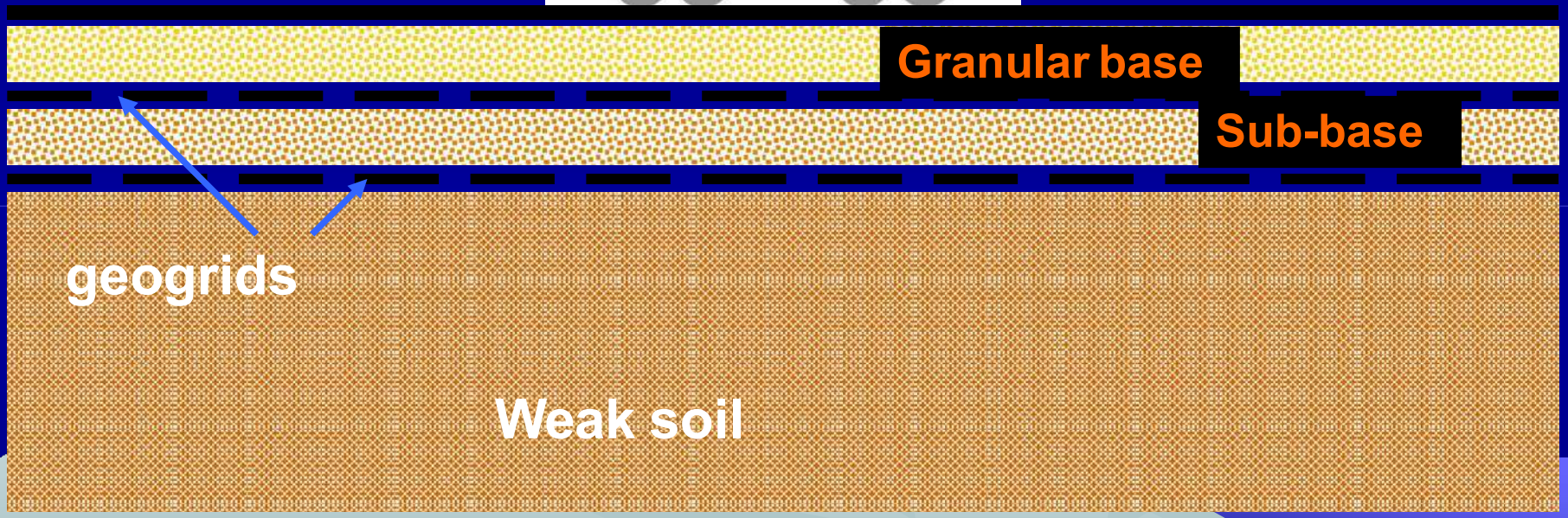
Weak soil

Reducing the Pressure on Sub-soil

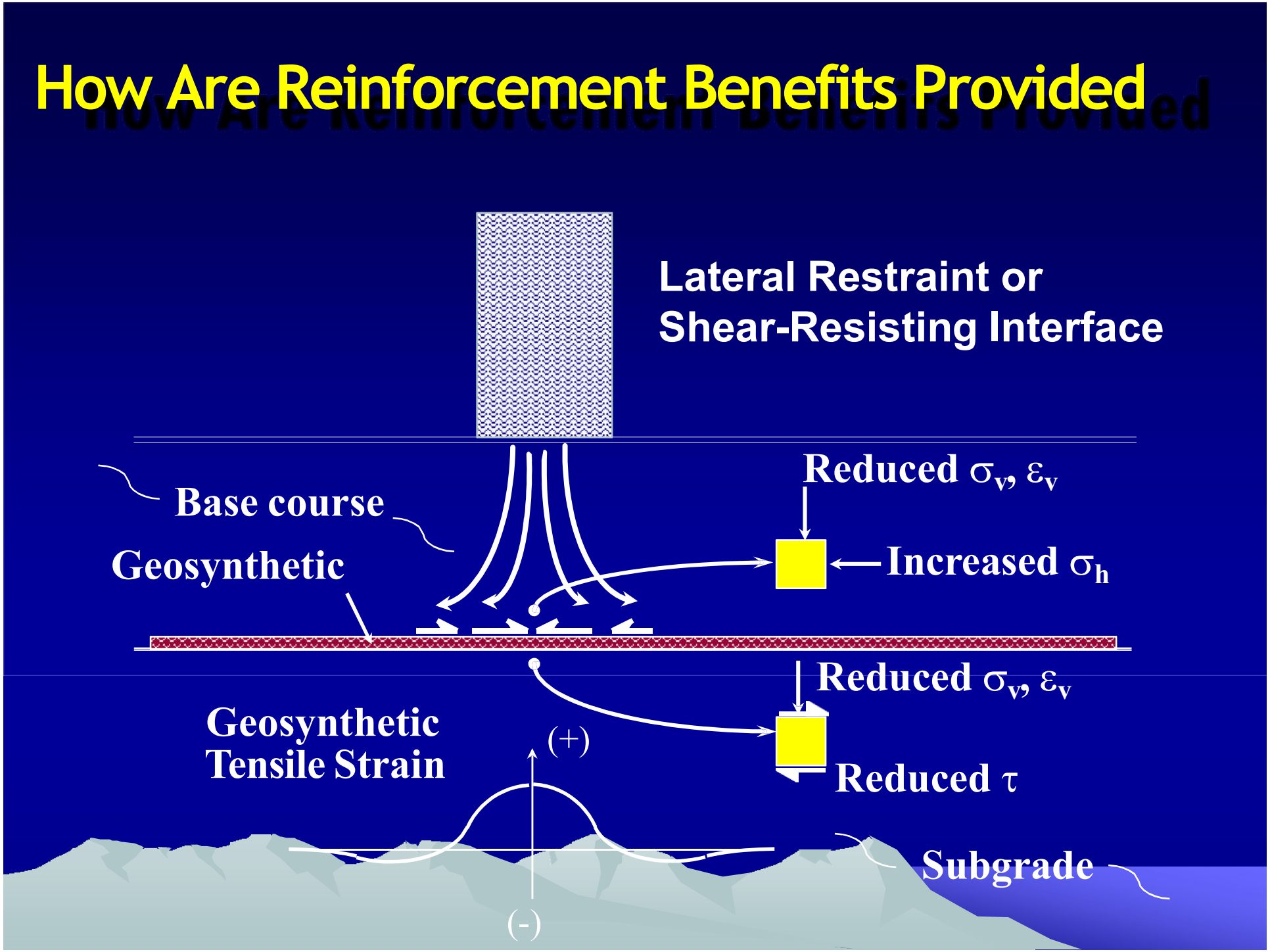


Construction WithGeogrid Reinforcement





How Are Reinforcement Benefits Provided



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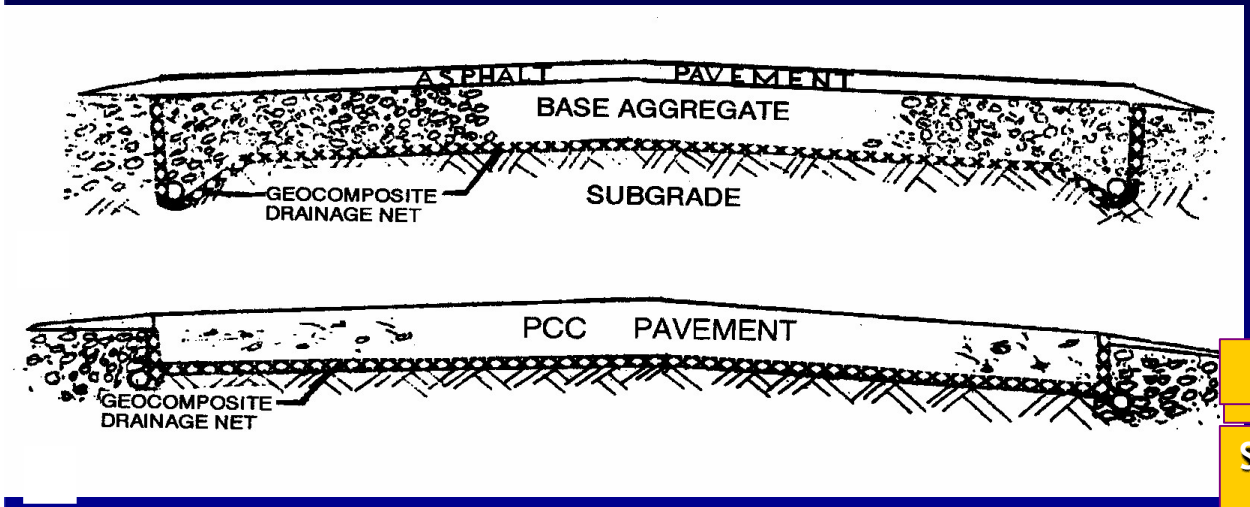
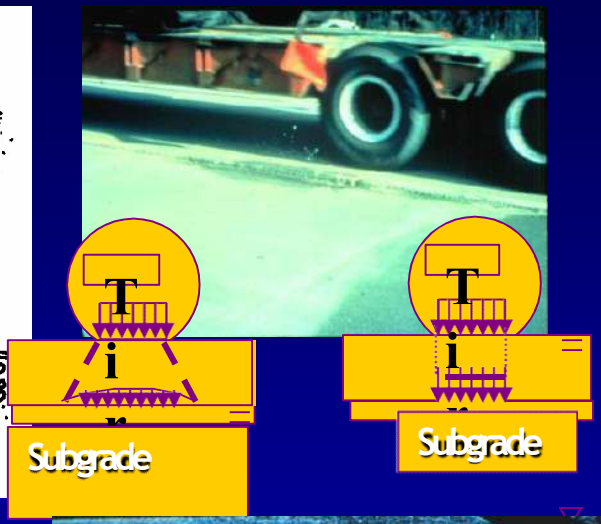
- Base Reinforcement
  - Benefit shown for subgrades up to CBR 8%
  - Geogrid primary function: reinforcement
  - Geogrid reinforcement is a function of lateral confinement
  - "Stiff" geogrids tend to provide better base reinforcement
  - Geotextiles/geogrids allow aggregate thickness reductions
- Construction Expedient
  - Geogrids serve as a compaction aid
  - Place aggregate full depth prior to spreading
  - "Stiff" geogrids can serve as walking platforms
  - Effective solution for temporary construction

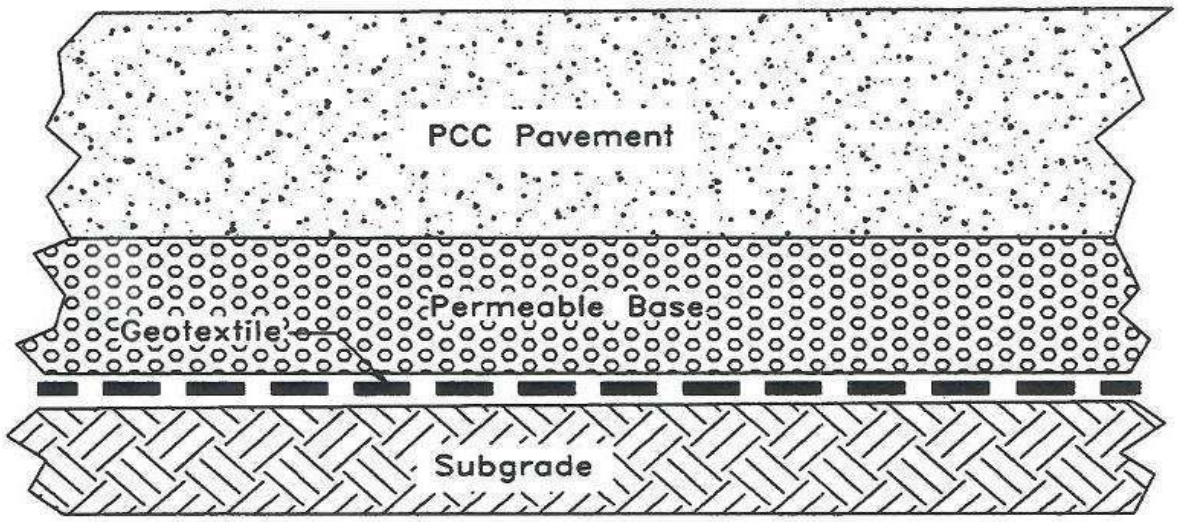
During Construction Time…

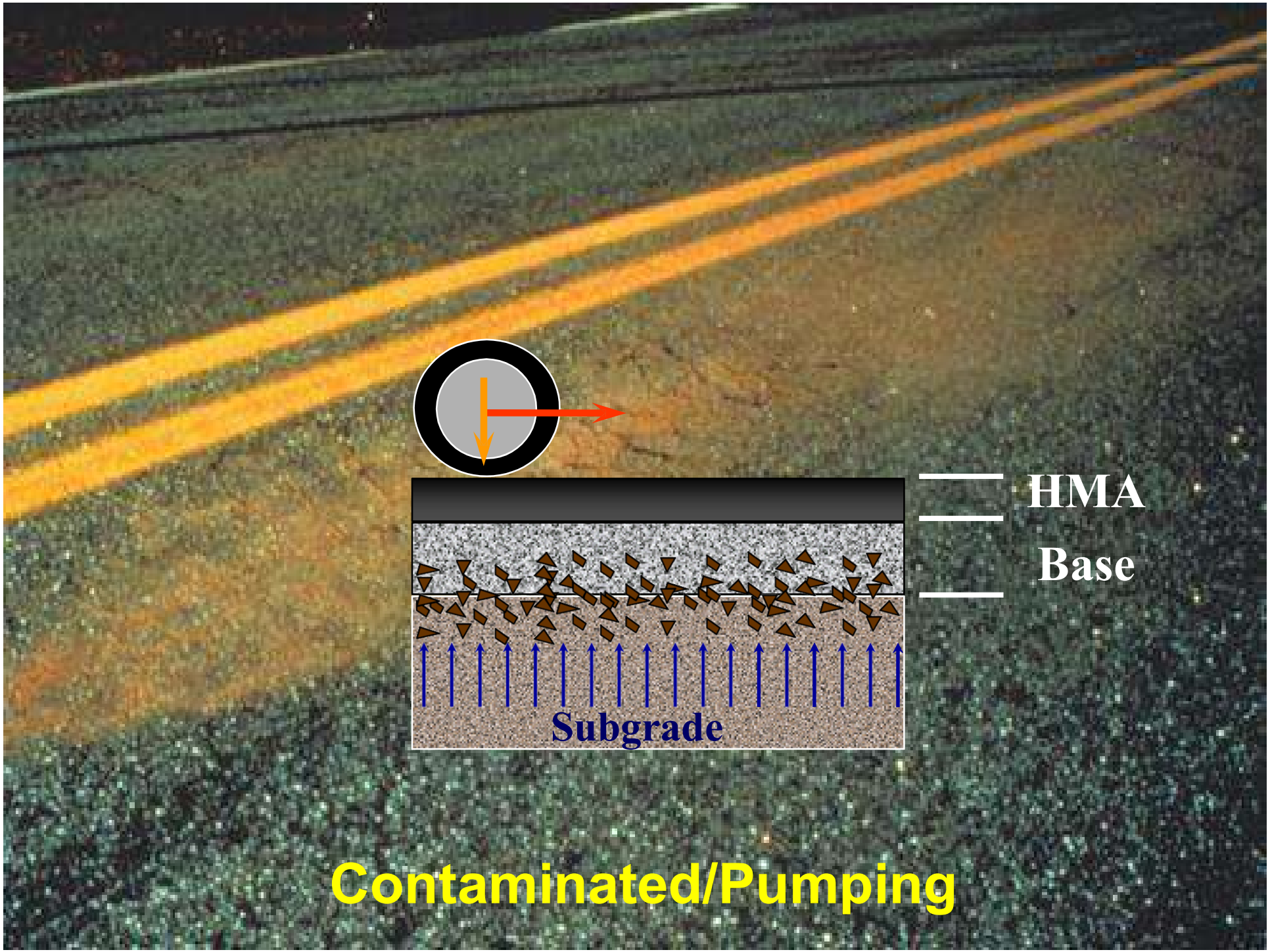
Quick and easy access to the site !

Drainag and Filtration



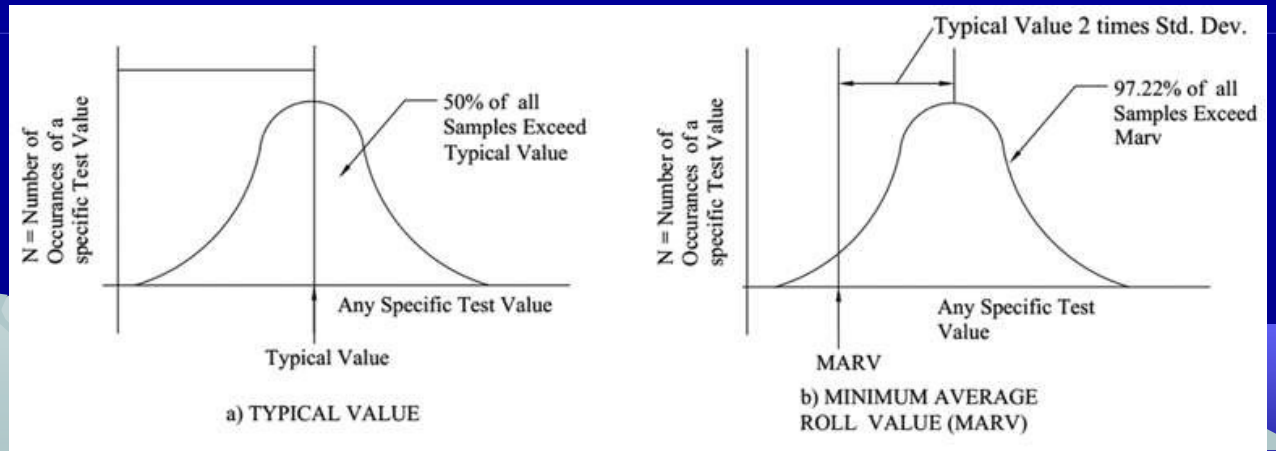





HMA
Base
Subgrade
Contaminated/Pumping

Properties and Test Methods For Geosynthetic

- GS shall be Tested and Certified in the following manner:
- The manufacturer shall have ISO certification and quality control.
- Shall provide manufacturer's test certificate for every lot supplied
- Shall provide third party test reports from an independent lab.
- GS shall be tested in accordance relevant BIS, ISO, ASTM.
- *'Typical Value' and 'Minimum Average Roll Value'!!*
- The "typical "refers to the avg or mean value and is valid for any GSM
  and 50 per cent can be expected to fall below this value.
- MARV is 97.7% as per IS 16362



Geotextile and Test Methods

- Physical properties
  - Specific gravity
  - Mass per unit area
  - Thickness
- Mechanical properties
  - Tensile strength
  - Puncture strength
  - Sewn seam strength
- Hydraulic properties
  - Apparent opening size (AOS)
  - Geotextile permittivity

Geotextile Properties and Test Methods

Type of Properties	Property Name	Test Met
Physical Properties	Mass per Unit Area	ASTM D 5261
	Thickness	ASTM D 5199
	Specific Gravity	ASTM D 1505
Mechanical Properties	Grab Strength & Elongation	ASTM D 4632
	Seam Strength	ASTM D 4884
	Trapezoid Tear Strength	ASTM D 4533
	Other - Burst, Puncture, Pullout strengths etc.	-
Hydraulic Properties	Apparent Opening Size	ASTM D 4751
	Permittivity (Cross-Plane Permeability)	ASTM D 4491/5463
	Transmissivity (In-Plane Permeability)	ASTM D 6574
Endurance Properties	Installation Damage	-
	Creep	ASTM D 5262
	Abrasion	ASTM D 4886
	UV Resistance	ASTM D 4355
	Temparature	ASTM D 4594
	Chemical Resistance	ASTM D 6389

Physical Properties

- Sp. Gr is the ratio of material's unit volume weight(without any voids) to that of distilled, de-aired water at 27°C.
  - Polypropylene : 0.91
  - Polyester : 1.22 to 1.38
  - Nylon : 1.05 to 1.14
  - Polyethylene : 0.90 to 0.96
  - Polyvinyl chloride : 1.69
- Mass per unit area governs the fabric cost and normally mechanical properties are directly related to it. Length and width should be measured under zero tension induced in geotextile.
- The range of typical values for most geotextiles is100 to1000 gm/m2.
- The thickness of geotextiles ranges from 0.25 to 7.5 mm

Mechanical Properties

- For tensile properties use a wide-width Strip method. The geotextiles when tensioned tend to have a severe necking effect under increasing stress and they rope up, giving artificially high values.
- Grab strength test will also conducted for the determination of tensile properties of geotextiles- ISO 13934 or IS 16342 or ASTM D4632.
- Puncture strength: Assessment of geotextile resistance to objects, such as, rocks or pieces of wood. ISO 12236, IS:13162 (Part 4) and ASTM D6241.
- Sewn seam strength: Seam strength is typically evaluated in the laboratory using ISO10321 "Geosynthetics- Tensile test for joints/seams by wide-width strip method" or IS 15060or ASTM D4884,

Geosynthetic Applicability Assessment For Aggregate-Surfaced Pavements

Case01: Subgrade CBR <= 0.5, adopt mechanical subgrade stabilization

- Ω Nonwoven geotextile is recommended for separation
- Ω Biaxial geogrid is recommended for aggregate reinforcement
- Ω Aggregate fill should be used and no reduction in aggregate thickness.
- Ω Nonwoven geotextile is placed directly on the subgrade-geogrid- aggregate fill

Case 02: Subgrade 0.5 < CBR 2.0.

- Ω Stabilization and base reinforcement applications are mobilized.
- Ω A nonwoven is recommended for separation at subgrade strengths <2.0 CBR
- Ω Aggregate thickness can be reduced- Use bearing capacity factor

Case 03: Subgrade 2.0 < CBR 4.0

- Ω Nonwoven geotextile- Separation for fine-grained subgrades with CBR <=4. Ω CBR b/w 2.0 and 4.0, the primary geogrid application is base reinforcement. Ω Bearing capacity factor for the inclusion of both a geotextile and a geogrid.

Case 04: Subgrade CBR > 4.0.

- Ω Reinforcement potential at these subgrade strength. geogrid reinforcement is
- Ω Cost-prohibitive for projects in which the design subgrade CBR strength is > 4.0

Guidelines for Use of Geosynthetics in Road Work

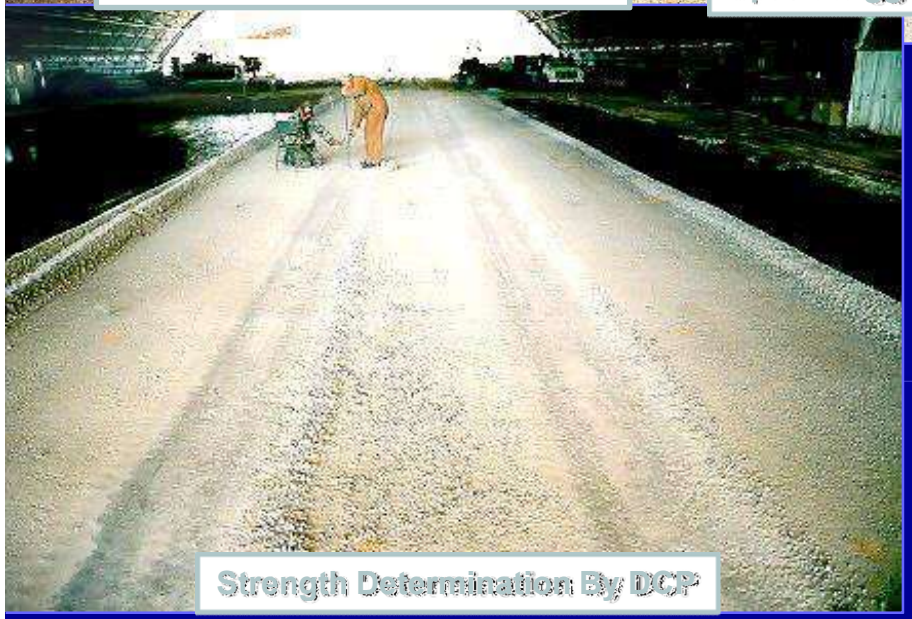
- The material properties are only one factor in a successful installation using geosynthetics.
- Proper construction and installation techniques are essential in order to
  ensure that the intended function of geosynthetics is fulfilled.
- Though, the installation techniques appear fairly simple, most geosynthetic problems in roadways occur as a result of improper construction techniques.
- If the geosynthetic not handled properly during construction activities, it will not perform as desired. If the geosynthetic is placed with lot of wrinkles or folds, it will not be in tension and, therefore, cannot provide a reinforcing effect.
- Step-by-step procedure should be followed in different construction activities with geosynthetics.

General Road Construction

Full-Depth Aggregate Placement

Spread Aggregate To Shoulders

Traffic



Strength Determination By DCP

Reinforced Section

Unreinforced Section

Construction Guidelines for Subsurface Drainage

Step 1: Trench excavation shall be done as per designs/ requirements.

Step 2: Geosynthetic material shall be placed loosely with no wrinkles or folds. Sheets of geosynthetics shall be overlapped a minimum of 300 mm with the upstream sheet overlapping the downstream sheet.

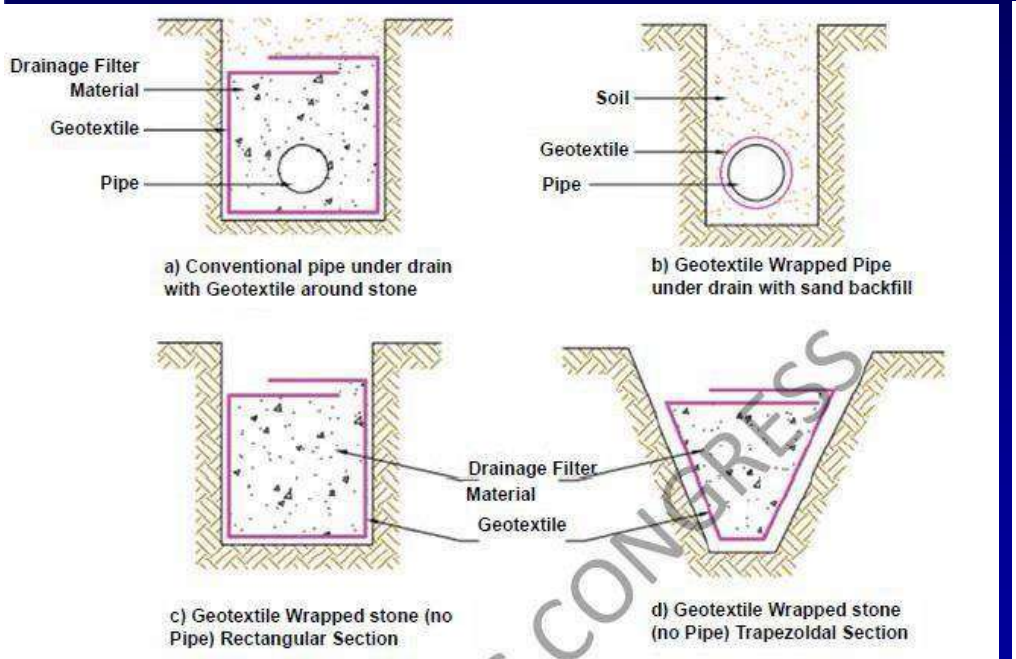
Step 3: (a)Trenches = or >to 300 mm in width, after placing the design filter material, the GS shall be folded over the top of the backfill material in a manner to produce a min. overlap of 300 mm.

(b)Trenches <300 mm, but>100 mm wide, the overlap shall be equal to the width of the trench. (c) Trench <100 mm, the geosynthetic overlap shall be bonded

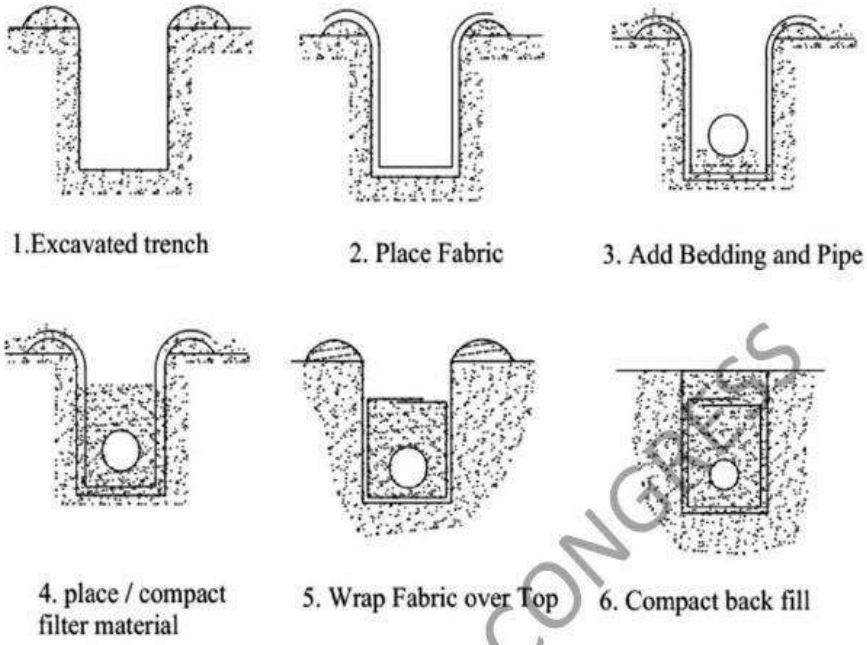
Step 4: Placement of design filter material should proceed immediately after placement of the GS material. The geosynthetic should be covered with a minimum of 300 mm of loosely placed aggregate prior to compaction. If a perforated collector pipe is to be installed in the trench, a bedding layer of drainage aggregate should be placed below the pipe, with the remainder of the aggregate placed to the minimum required construction depth.

Step 5: The aggregate should be compacted to a minimum of 90 per cent of standard proctor density.

Contd….Contd….



Arrangements for trench Drains



Sequence of Works for Drains

Guidelines for Separation/Filtration/Subgrade/Base/Subbase Reinforcement Function

. Step 1: Clear any unsuitable materials. If moderate site conditions exist, i.e., CBR >1, lightweight profiling operations should be considered to locate unsuitable materials. Isolated pockets where additional excavation is required should be backfilled.

Step2: Care should be taken not to excessively disturb the subgrade. This may require the use of lightweight dozers or graders for low strength, saturated, on-cohesive &low-cohesive soils. The subgrade preparation must correspond to the survivability propertiesofthe geosynthetic.

Step 3: Once the subgrade is prepared the geosynthetic should be rolled in line with the placement of the aggregate. The geosynthetic should not able dragged across the subgrade. The entire roll should be placed and rolled out as smoothly as possible.

Step 4: Adjacent rolls of geosynthetic should be overlapped. Folds in the geosynthetic should be stapled or pinned approximately 0.6 m c/c.

Step 5: If excessive defects are observed, the section of the geosynthetic material containing the defect should be repaired by placing a new layer of geosynthetic over the damaged area in case of geotextiles and geomembrane for separation, drainage and capillary barrier applications.

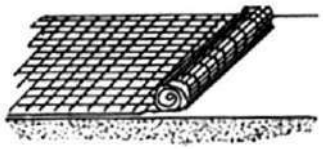
Step 6: In case of geogrids and geocells for reinforcement and stabilization function, if the material is damaged, placing a new layer over damaged portion won't provide membrane effect and intended function may not fulfil. In those cases replacing with a new material for entire design role length of geosynthetic material in transverse directions advisable.

Step 7: The first lift of aggregate should be spread and graded to 300 mm, or to design thickness if less than 300 mm prior to compaction. At no time should traffic be allowed on a soft roadway with less than 200 mm of aggregate over the geosynthetic.

Step 8: Any ruts that form during construction should be filled to maintain adequate cover over the geosynthetic. Base aggregates should be placed in lifts not exceeding 250 mm in loose thickness and compacted to the specified density.

1 **Prepare the Ground**

a. PREPARE THE GROUND BY REMOVING STUMPS, BOULDERS, ETC; FILL IN LOW SPORTS

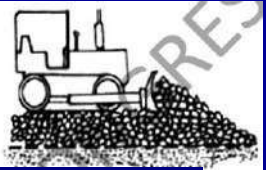


2 **Unroll the Geotextile**

b. UNROLL THE GEOTEXTILE DIRECTLY OVER THE GROUND TO BE STABILIZED. IF MORE THAN ONE ROLL IS REQUIRED, OVERLAP ROLLS. INSPECT GEOTEXTILES

3 **Back Dump Aggregate**

c. BACK DUMP AGGREGATE ON TO PREVIOUSLY PLACED AGGREGATE. DO NOT DRIVE ON THE GEOTEXTILE. MAINTAIN 150mm TO 300mm COVER BETWEEN TRUCK TYRES AND GEOTEXTILE



4 **Spread the Aggregate**

d. SPREAD THE AGGREGATE OVER THE GEOTEXTILE TO THE DESIGN THICKNESS

5 **Compaction the Aggregate**

e. COMPACT THE AGGREGATE USING DOZER TRUCK OR SMOOTH DRUM VIBRATORY ROLLER

Overlap of Geosynthetics

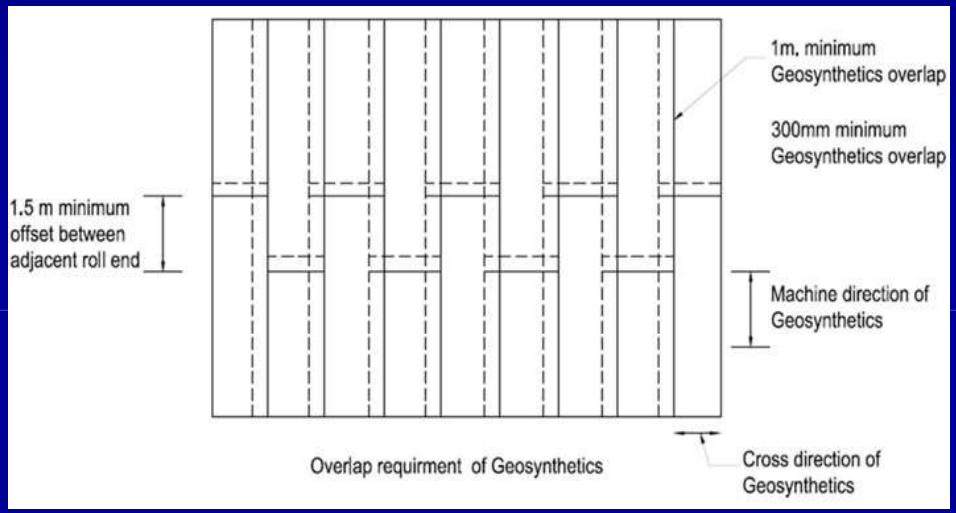
- If the subgrade does not rut under construction activities, only minimum overlap is required to provide some pull-out resistance. As the potential for rutting and squeezing of soil increases, the required overlap increases. Since rutting potential can be related to CBR, it can be used as a guideline for the minimum overlap required.

Table 5.1 Overlap Requirement of Geotextile for Different CBR Values (IS 16345)

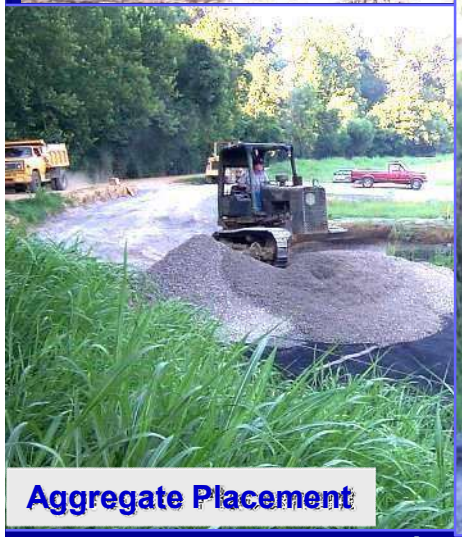
Soil Strength (CBR)	Overlap Unsewn, cm	Overlap Sewn, cm
Greater than 3 and above	60	-
2-3	76	8
1-2	97	20
Less than 1	-	23
All Roll Ends	100	25

Table 5.2 Overlap Requirement of Geogrid for Different CBR Values (IS 16349)

Soil Strength (CBR)	Method of Joining (mm)
Greater than 3	300-450
1-3	600-1000
0.5-1	1000 or sewn
Less than 0.5	sewn
All Roll Ends	1000 or sewn

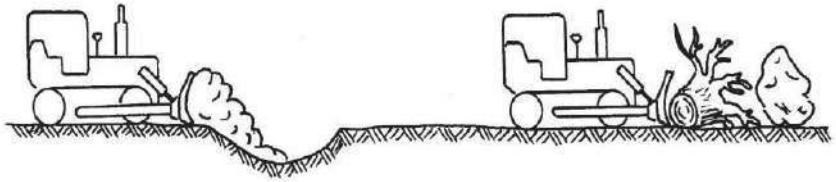


Road Construction Over Soft grounds



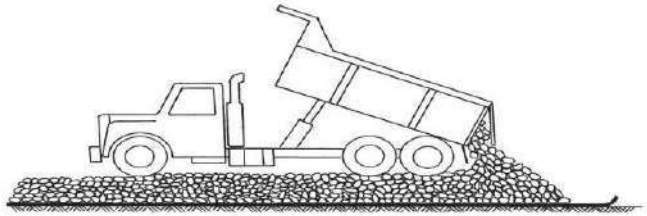
Alternate Lightweight Fills
- Wood Chips (Temp. Roads Only)
- Sand

Subgrade Separation and Reinforcement

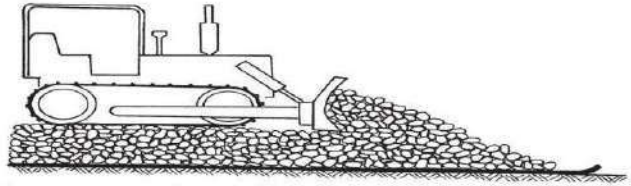


A. Prepare the ground by removing stumps, boulders, etc. Fill in the low spots.

B. Unroll the geotextile directly over the ground to be stabilized. If more than one roll is required, overlap the rolls. Inspect the geotextile and pull it out tight. Stake down as needed.



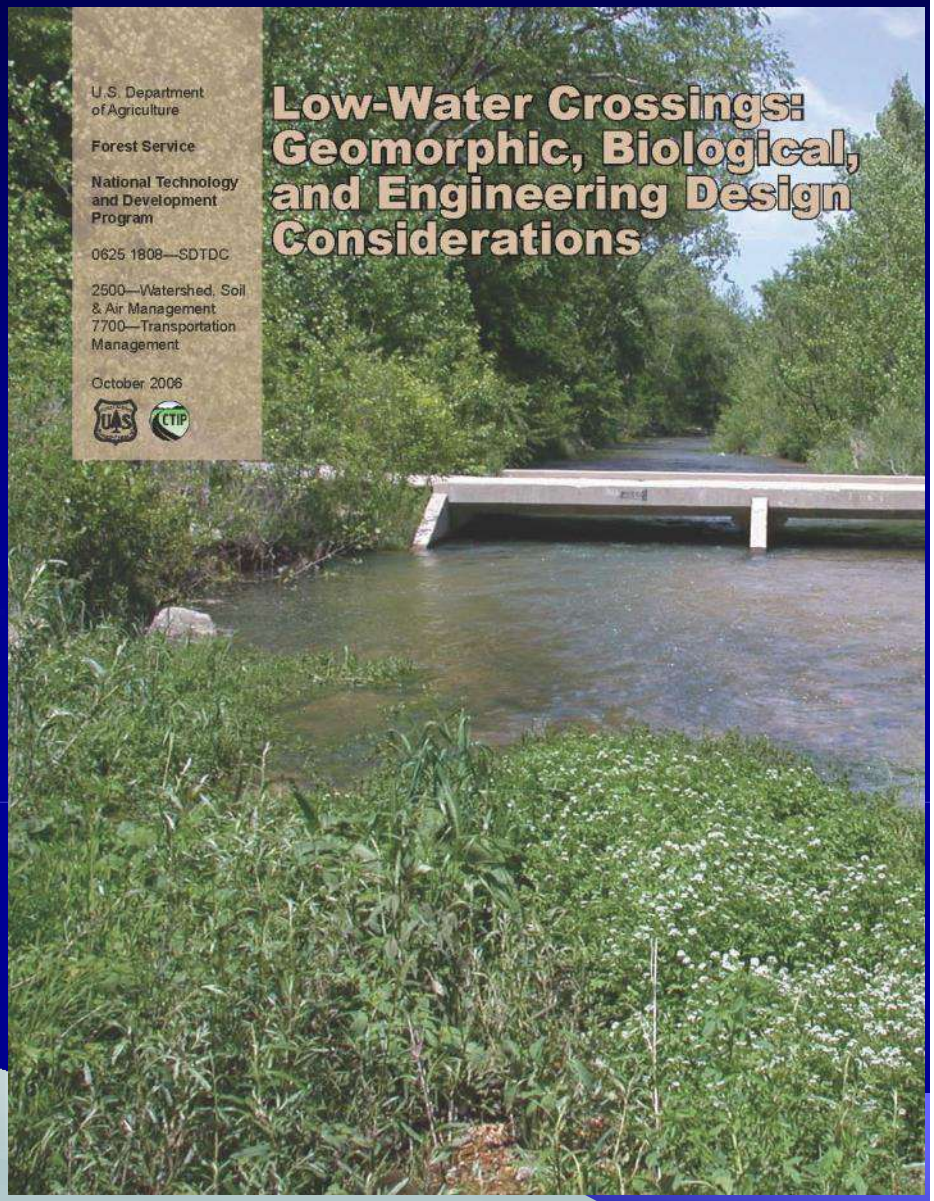
C. Back dump aggregate onto the previously placed aggregate. Do not drive on the geotextile. Maintain 6 to 12 inches (150 to 300 mm) cover between the truck tires and geotextile.



D. Spread the aggregate over the geotextile to the design thickness. Finally, compact the aggregate using dozer tracks or smooth drum vibratory roller.

Erosion Control Netting and Turffing

Geocell Confinement in Low Water Crossings



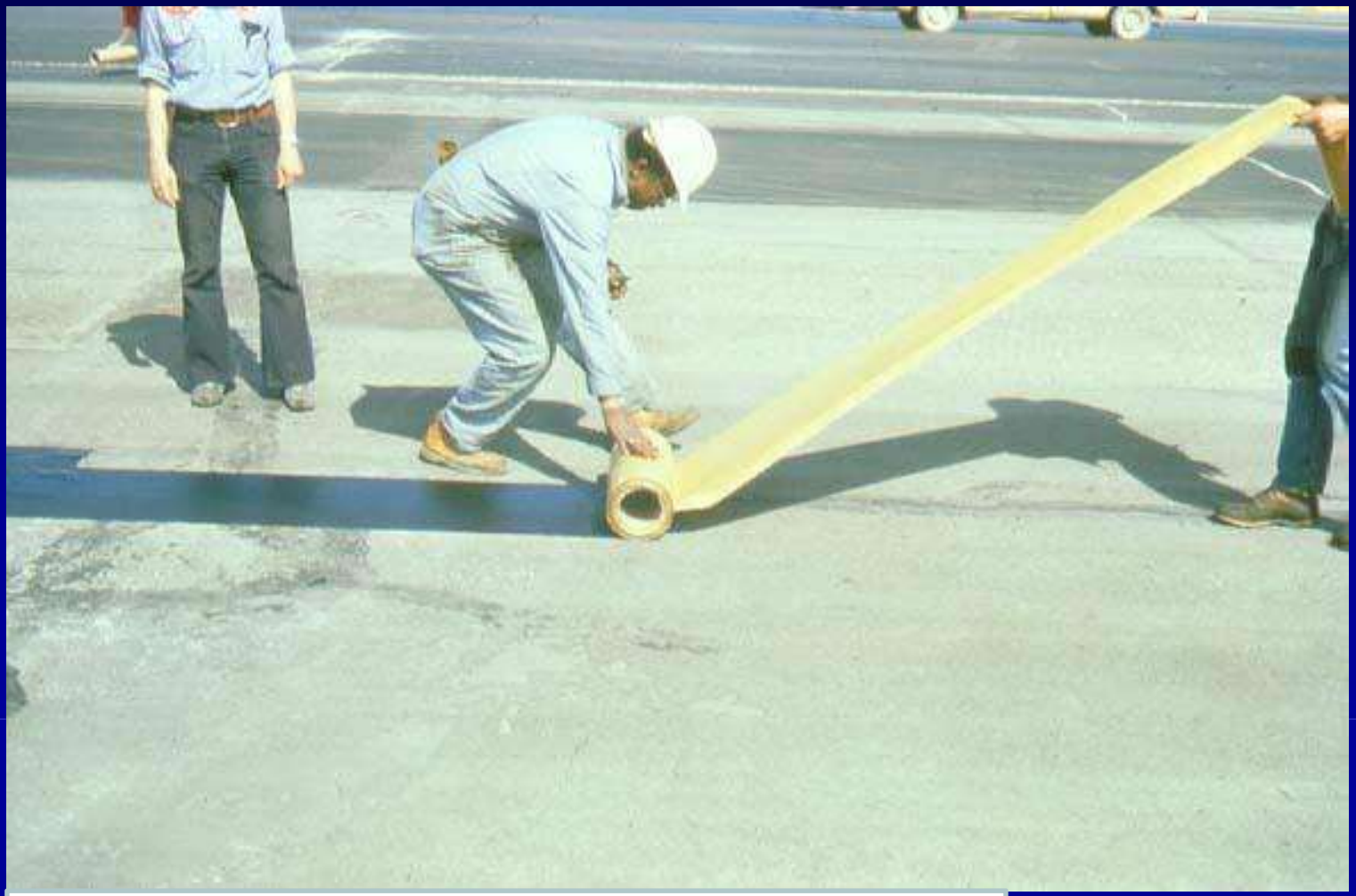
Geo Protection-Fencing

Sealed Crack

Fatigue Cracking and Rutting

Remove Rutted/Fatigue Section and Repair Subgrade/Base

Patch Repaired Section



Band-Aid Interlayer for PCC or Reflective Cracking

Seat Interlayer Material with Modern Equipment

Apply Tack Coat at 0.26 gallons/yd^2
Problems: Clean Nozzles, Adjust Spray Height, Ensure Spray Overlap,
Adjust Spray Bar Height, Watch Out for Mischievous Onlookers

Use Automated Equipment to Place Fabric If Possible

Place Fabric Immediately After Tack Coat Application

Ensure Proper Tensioning of Fabric to Prevent Wrinkles

Place Fabric Along Edges First, Then Place Center Fabric with 6 in. Overlap.

Seat Fabric With Pneumatic Roller to Ensure Intimate Contact With Surface

Fabric in Curves Must be Placed By Hand and Broomed Into Place

Fabric Edge Should Be Folded Back 6 in. to Start a New Roll

Transverse Joints Can Be Tacked In Place

Pave Surface

Finished Product

Place Aggregate In Center of Traffic Lane and Spread Towards Shoulders

Place Geotextile Separator Directly On The Subgrade

Aggregate Placed In Center and Spread To Shoulders Over Geosynthetics

Rutted Section of Unreinforced Road

Subgrade

Geotextile Placement

Aggregate Placement – Avoid Thin Lifts (Probably Too Thin Here)

Spread Aggregate From Center to Shoulders

Rear Dumped Aggregate

Spreading Aggregate With A Grader – Avoid Graders During Initial Lift
- Use Front-Bladed Equipment to Prevent Rutting and Damage to Fabric

Establish Final Grade With A Grader – Ready For Compaction

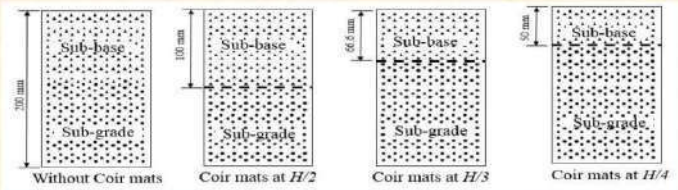
Works at NITW

Laboratory Experimental Program

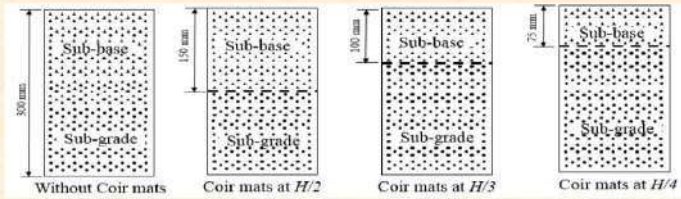
Experimental setup with 300 x300 x 200mm fabricated mould

Experimental setup with 300 x300 x 300mm fabricated mould

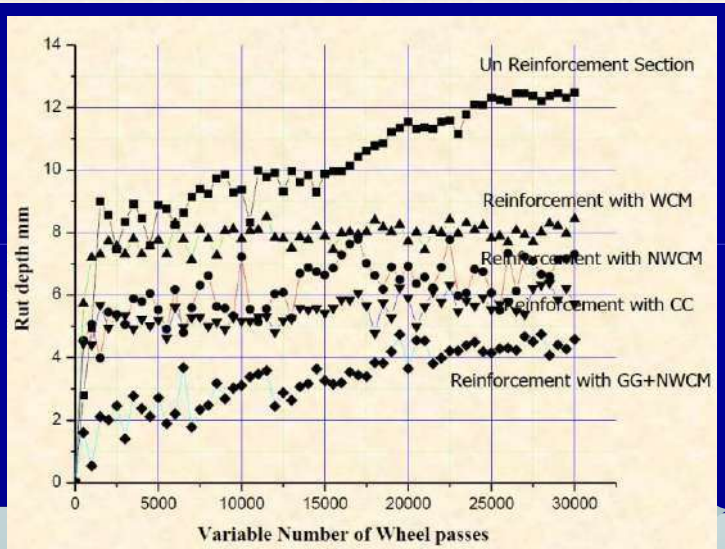
POSITION OF COIR MATS IN THE FABRICATED MOULD



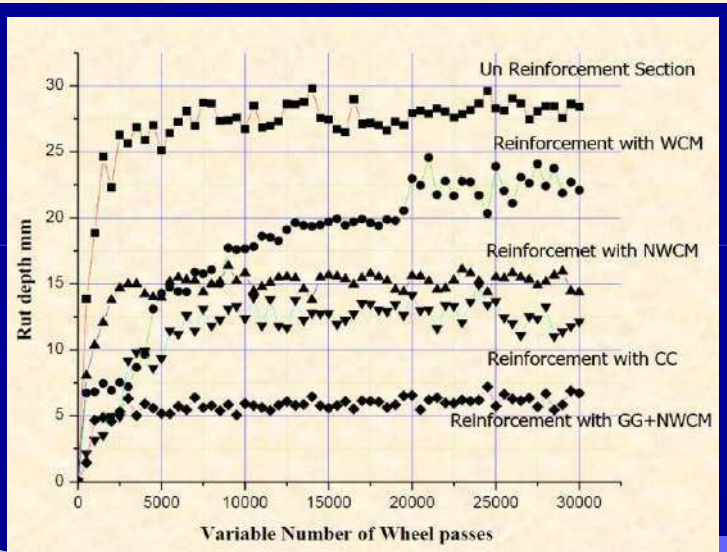
Placement of coir mats 300x300x200mm fabricated mould



Placement of coir mats 300x300x300mm fabricated mould



Rut depth and number of wheel passes at H/2 position of morrum soil



Rut depth and number of wheel passes at H/3 position of morrum soil

Un-reinforcement and reinforcement tested sample

Without Reinforcement

H/2

H/3

H/4

With Reinforcement

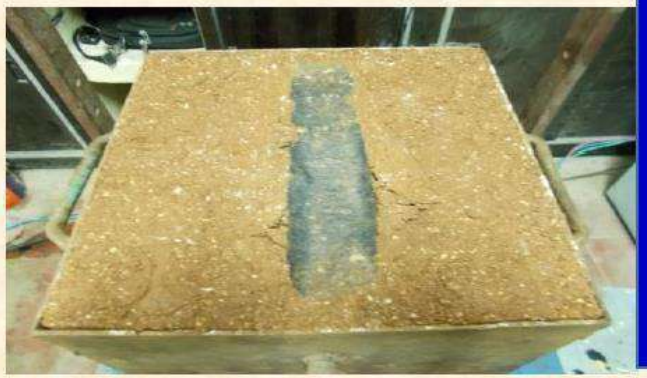
Laboratory work

Without Reinforcement

H/2

H/3

H/4



With Reinforcement

In-Situ Evaluation-APT

Preparation Subgrade

Compacted Subgrade by roller

Installation of load cell and strain gauge

Installation of coir geotextile

Preparation of sub-base with morrum soil

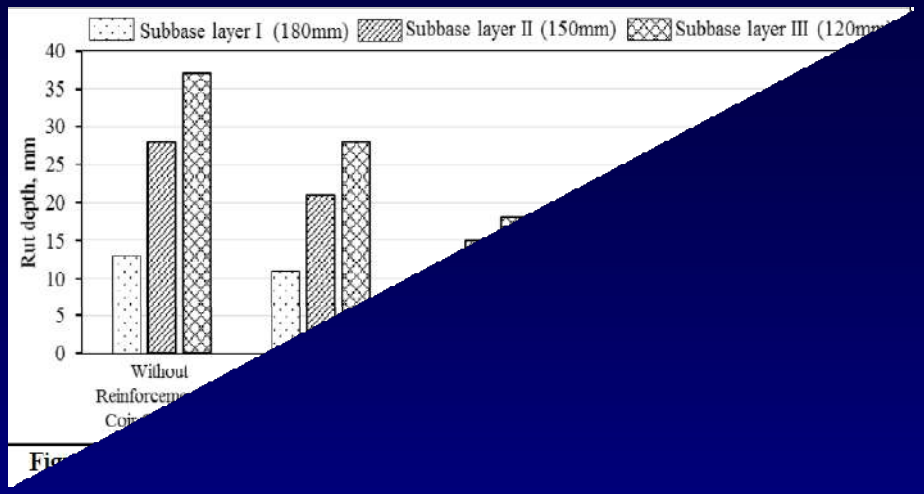
Preparation of sub-base and installation of sensor

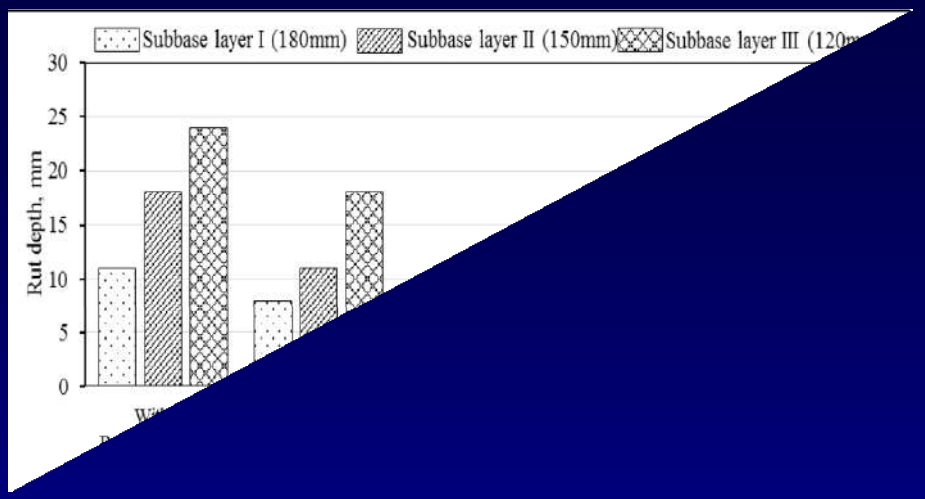
Compacted sub-base with gravel soil

Preparation of sub-base before test

Preparation of sub-base after test

Contd..





S. No	Description	Type of Coir Geotextile	Total thickness (mm)	Saving of sub-base material (mm)
1	Conventional Pavement thickness	Without geotextile	480	-
2	Adopted thickness	With Woven coir mats	350	130
3	Adopted thickness	Coir composite	369	111
4	Adopted thickness	Combination of GG and NWCM	373	107

Summary

- Assessment of the suitability of a project and selection of appropriate geosynthetic type are most important.
- Geosynthetics offer a wide range of solutions LVRs.
- GS can facilitate construction and be very cost-effective.
- Many simplifying soil correlations and basic GS can appropriately be used
- GS are generally under-utilized on LVR projects.